

1 We claim:

1 1. A method to adjust the data transfer rate for one of (N) primary backup  
2 appliances, wherein each of said (N) primary backup appliances is capable of  
3 communicating with one or more first data storage and retrieval systems and with one or  
4 more secondary backup appliance capable of communicating with one or more second  
5 data storage and retrieval systems, comprising the steps of:

6 providing a first one of said (N) primary backup appliances, wherein said first  
7 primary backup appliance is capable of communicating with a first one of said one or  
8 more secondary backup appliances;

9 forming by said first primary backup appliance at least one consistent transactions  
10 set comprising information received from said one or more first data storage and retrieval  
11 systems;

12 receiving the (n)th status signal from each of the other (N-1) primary backup  
13 appliances;

14 receiving the (n+1)th status signal from each of the other (N-1) primary backup  
15 appliances;

16 calculating the (n)th effective bandwidth for each of said (N) primary backup  
17 appliances;

18 calculating the (n)th time to complete for each of said (N) primary backup  
19 appliances;

20 calculating the (n)th effective aggregate bandwidth for all (N) primary appliances;

21 determining if the (n)th time to complete for said first primary backup appliance  
22 is greater than the (n)th time to complete for each of the other (N-1) primary backup  
23 appliances;

24 operative if the (n)th time to complete for said first primary backup appliance is  
25 greater than the (n)th time to complete for each of the other (N-1) primary backup  
26 appliances, providing all or part of at least one consistent transactions set from said first  
27 primary backup appliance to said first secondary backup appliance with no delay.

1 2. The method of claim 1, further comprising the steps of:

2 operative if the (n)th time to complete for said first primary backup appliance is  
3 not greater than the (n)th time to complete for each of the other (N-1) primary  
4 appliances, determining if the (n)th aggregate bandwidth is less than the (n-1) aggregate  
5 bandwidth;

6 operative if the (n)th aggregate bandwidth is not less than the (n-1) aggregate  
7 bandwidth, establishing the (n)th delay for said first primary backup appliance;  
8 providing all or part of at least one consistent transactions set from said first  
9 primary backup appliance to said secondary backup appliance using said (n)th delay.

1 3. The method of claim 2, further comprising the steps of:

2 operative if the (n)th aggregate bandwidth is less than the (n-1) aggregate  
3 bandwidth, determining if the (n-1)th delay for said first primary backup appliance is  
4 greater than the (n-2)th delay for said first primary backup appliance;

5 operative if the (n-1)th delay for said first primary backup appliance is greater  
6 than the (n-2)th delay for said first primary backup appliance, setting the (n)th delay for

7 said first primary backup appliance equal to the (n-2)th delay for said first primary  
8 backup appliance;  
9 providing all or part of at least one consistent transactions set from said first  
10 primary backup appliance to said secondary backup appliance using said (n)th delay.

1 4. The method of claim 3, further comprising the steps of:  
2 operative if the (n-1)th delay for said first primary backup appliance is not greater  
3 than the (n-2)th delay for said first primary backup appliance, establishing the (n)th delay  
4 for said first primary backup appliance;  
5 providing all or part of at least one consistent transactions set from said first  
6 primary backup appliance to said secondary backup appliance using said (n)th delay for  
7 said first primary backup appliance.

1 5. The method of claim 2, wherein said establishing step further comprises  
2 the steps of:  
3 determining the (n)th mean time to complete for all (N) primary backup  
4 appliances;  
5 determining if the (n)th time to complete for said first primary backup appliance  
6 substantially equals said (n)th mean time to complete;  
7 operative if the (n)th time to complete for said first primary backup appliance  
8 substantially equals said (n)th mean time to complete, setting the (n)th delay for said first  
9 primary backup appliance equal to the (n-1)th delay for said first primary backup  
10 appliance.

1           6.       The method of claim 5, wherein said establishing step further comprises  
2 the steps of:

3           providing a standard delay adjustment;

4           determining if the (n)th time to complete for said first primary backup appliance  
5 is greater than said (n)th mean time to complete;

6           operative if the (n)th time to complete for said first primary backup appliance is  
7 greater than said (n)th mean time to complete, setting said (n)th delay for said first  
8 primary backup appliance equal to the (n-1)th delay for said first primary backup  
9 appliance minus said standard delay adjustment.

1           7.       The method of claim 6, further comprising the step of:

2           operative if said the (n)th time to complete for said first primary backup appliance  
3 is less than said (n)th mean time to complete, setting said (n)th delay for said first  
4 primary backup appliance equal to the (n-1)th delay for said first primary backup  
5 appliance plus said standard delay adjustment.

1           8.       The method of claim 5, wherein said establishing step further comprises  
2 the steps of

3           providing a delay adjustment function;

4           determining the difference between said (n)th mean time to complete and the (n)th  
5 time to complete for said first primary backup appliance;

6           establishing the (n)th delay for said first primary backup appliance based upon  
7 said difference and said delay adjustment function.

1           9.       The method of claim 5, wherein said establishing step further comprises  
2 the steps of:  
3           providing a standard delay adjustment;  
4           predicting the (n)th delay for each of said (N-1) remaining primary backup  
5 appliances using said (n)th mean time to complete, the (n)th time to complete for each of  
6 the (N-1) remaining primary backup appliances, and said standard delay adjustment;  
7           establishing the (n)th delay for the first primary backup appliances based upon the  
8 predicted delays for each of said (N-1) remaining primary backup appliances.

1           10.     The method of claim 2, wherein said establishing step further comprises  
2 the steps of  
3           providing a delay adjustment function;  
4           predicting using said delay adjustment function (N-1) delay values, wherein each  
5 of said predicted delay values is associated with a different one of the remaining (N-1)  
6 primary backup appliances;  
7           establishing the (n)th delay for the first primary backup appliances based upon  
8 said (N-1) predicted delay values.

1           11.     An article of manufacture comprising a computer useable medium having  
2 computer readable program code disposed therein to adjust the data transfer rate for a  
3 first one of (N) primary backup appliances, wherein each of said (N) primary backup  
4 appliances is capable of communicating with one or more first data storage and retrieval  
5 systems and with one or more secondary backup appliances capable of communicating  
6 with one or more second data storage and retrieval systems, and wherein said article of

7 manufacture is capable of communicating with a first one of said plurality of secondary  
8 backup appliances, the computer readable program code comprising a series of computer  
9 readable program steps to effect:  
10 forming at least one consistent transactions set comprising information received  
11 from said one or more first data storage and retrieval systems;  
12 receiving the (n)th status signal from each of the other (N-1) primary backup  
13 appliances;  
14 receiving the (n+1)th status signal from each of the other (N-1) primary backup  
15 appliances;  
16 calculating the (n)th effective bandwidth for each of said (N) primary backup  
17 appliances;  
18 calculating the (n)th time to complete for each of said (N) primary backup  
19 appliances;  
20 calculating the (n)th effective aggregate bandwidth for all (N) primary appliances;  
21 determining if the (n)th time to complete for said article of manufacture is greater  
22 than the (n)th time to complete for each of the other (N-1) primary backup appliances;  
23 operative if the (n)th time to complete for said article of manufacture is greater  
24 than the (n)th time to complete for each of the other (N-1) primary backup appliances,  
25 providing all or part of at least one consistent transactions set to said first secondary  
26 backup appliance with no delay.

1 12. The article of manufacture of claim 11, said computer readable program  
2 code further comprising a series of computer readable program steps to effect:

3           operative if the (n)th time to complete for said article of manufacture is not  
4   greater than the (n)th time to complete for each of the other (N-1) primary appliances,  
5   determining if the (n)th aggregate bandwidth is less than the (n-1) aggregate bandwidth;  
6           operative if the (n)th aggregate bandwidth is not less than the (n-1) aggregate  
7   bandwidth, establishing the (n)th delay for said article of manufacture;  
8           providing all or part of at least one consistent transactions set to said first  
9   secondary backup appliance using said (n)th delay.

1           13.    The article of manufacture of claim 12, said computer readable program  
2   code further comprising a series of computer readable program steps to effect:

3           operative if the (n)th aggregate bandwidth is less than the (n-1) aggregate  
4   bandwidth, determining if the (n-1)th delay for said article of manufacture is greater than  
5   the (n-2)th delay for said article of manufacture;

6           operative if the (n-1)th delay for said article of manufacture is greater than the (n-  
7   2)th delay for said first primary backup appliance, setting the (n)th delay for said article  
8   of manufacture equal to the (n-2)th delay for said article of manufacture;  
9           providing all or part of at least one consistent transactions set to said first  
10   secondary backup appliance using said (n)th delay.

1           14.    The article of manufacture of claim 13, said computer readable program  
2   code further comprising a series of computer readable program steps to effect:

3           operative if the (n-1)th delay for said article of manufacture is not greater than the  
4   (n-2)th delay for said article of manufacture, establishing the (n)th delay for said article  
5   of manufacture;

6 providing all or part of at least one consistent transactions set to said first  
7 secondary backup appliance using said (n)th delay.

1 15. The article of manufacture of claim 12, said computer readable program  
2 code further comprising a series of computer readable program steps to effect:

3 determining the (n)th mean time to complete for all (N) primary backup  
4 appliances;

5 determining if the (n)th time to complete for said article of manufacture  
6 substantially equals said (n)th mean time to complete;

7 operative if the (n)th time to complete for said article of manufacture substantially  
8 equals said (n)th mean time to complete, setting the (n)th delay for said article of  
9 manufacture equal to the (n-1)th delay for said article of manufacture.

1 16. The article of manufacture of claim 15, said computer readable program  
2 code further comprising a series of computer readable program steps to effect:

3 receiving a standard delay adjustment;

4 determining if the (n)th time to complete for said article of manufacture is greater  
5 than said (n)th mean time to complete;

6 operative if said the (n)th time to complete for said article of manufacture is  
7 greater than said (n)th mean time to complete, setting said (n)th delay for said article of  
8 manufacture equal to the (n-1)th delay for said article of manufacture minus said standard  
9 delay adjustment.

1 17. The article of manufacture of claim 16, said computer readable program  
2 code further comprising a series of computer readable program steps to effect:



3           operative if said the (n)th time to complete for said article of manufacture is less  
4   than said (n)th mean time to complete, setting said (n)th delay for said article of  
5   manufacture equal to the (n-1)th delay for said article of manufacture plus said standard  
6   delay adjustment.

1           18.    The article of manufacture of claim 15, said computer readable program  
2   code further comprising a series of computer readable program steps to effect:  
3           receiving a delay adjustment function;  
4           determining the difference between said (n)th mean time to complete and the (n)th  
5   time to complete for said article of manufacture;  
6           establishing the (n)th delay for said article of manufacture based upon said  
7   difference and said delay adjustment function.

1           19.    The article of manufacture of claim 15, said computer readable program  
2   code further comprising a series of computer readable program steps to effect::  
3           receiving a standard delay adjustment;  
4           predicting the (n)th delay for each of said (N-1) remaining primary backup  
5   appliances using said (n)th mean time to complete, the (n)th time to complete for each of  
6   the (N-1) remaining primary backup appliances, and said standard delay adjustment;  
7           establishing the (n)th delay for the article of manufacture based upon the  
8   predicted delays for each of said (N-1) remaining primary backup appliances.

1           20.    The article of manufacture of claim 12, said computer readable program  
2   code further comprising a series of computer readable program steps to effect:  
3           receiving a delay adjustment function;

4            predicting using said delay adjustment function (N-1) delay values, wherein each  
5    of said predicted delay values is associated with a different one of the remaining (N-1)  
6    primary backup appliances;

7            establishing the (n)th delay for said article of manufacture based upon said (N-1)  
8    predicted delay values.

1            21.    A computer program product usable with a usable with a programmable  
2    computer processor having computer readable program code embodied therein to adjust  
3    the data transfer rate for a first one of (N) primary backup appliances, wherein each of  
4    said (N) primary backup appliances is capable of communicating with one or more first  
5    data storage and retrieval systems and with one or more secondary backup appliances  
6    capable of communicating with one or more second data storage and retrieval systems,  
7    and wherein said first primary backup appliance is capable of communicating with a first  
8    one of said plurality of secondary backup appliances, comprising:  
9            computer readable program code which causes said programmable computer  
10   processor to form at least one consistent transactions set comprising information received  
11   from said one or more first data storage and retrieval systems;  
12            computer readable program code which causes said programmable computer  
13   processor to receive the (n)th status signal from each of the other (N-1) primary backup  
14   appliances;  
15            computer readable program code which causes said programmable computer  
16   processor to receive the (n+1)th status signal from each of the other (N-1) primary  
17   backup appliances;

18 computer readable program code which causes said programmable computer  
19 processor to calculate the (n)th effective bandwidth for each of said (N) primary backup  
20 appliances;

21 computer readable program code which causes said programmable computer  
22 processor to calculate the (n)th time to complete for each of said (N) primary backup  
23 appliances;

24 computer readable program code which causes said programmable computer  
25 processor to calculate the (n)th effective aggregate bandwidth for all (N)primary  
26 appliances;

27 computer readable program code which causes said programmable computer  
28 processor to determine if the (n)th time to complete for said first primary backup  
29 appliance is greater than the (n)th time to complete for each of the other (N-1) primary  
30 backup appliances;

31 computer readable program code which, if the (n)th time to complete for said first  
32 primary backup appliance is greater than the (n)th time to complete for each of the other  
33 (N-1) primary backup appliances, causes said programmable computer processor to  
34 provide all or part of at least one consistent transactions set to said first secondary backup  
35 appliance with no delay.

1 22. The computer program product of claim 21, further comprising:

2 computer readable program code which, if the (n)th time to complete for said first  
3 primary backup appliance is not greater than the (n)th time to complete for each of the

4 other (N-1) primary appliances, causes said programmable computer processor to  
5 determine if the (n)th aggregate bandwidth is less than the (n-1) aggregate bandwidth;  
6 computer readable program code which, if the (n)th aggregate bandwidth is not  
7 less than the (n-1) aggregate bandwidth, causes said programmable computer processor to  
8 establish the (n)th delay for said first primary backup appliance;  
9 computer readable program code which causes said programmable computer  
10 processor to provide all or part of at least one consistent transactions set to said secondary  
11 backup appliance using said (n)th delay.

1 23. The computer program product of claim 22, further comprising:  
2 computer readable program code which, if the (n)th aggregate bandwidth is less  
3 than the (n-1) aggregate bandwidth, causes said programmable computer processor to  
4 determine if the (n-1)th delay for said first primary backup appliance is greater than the  
5 (n-2)th delay for said first primary backup appliance;  
6 computer readable program code which, if the (n-1)th delay for said first primary  
7 backup appliance is greater than the (n-2)th delay for said first primary backup appliance,  
8 causes said programmable computer processor to set the (n)th delay for said first primary  
9 backup appliance equal to the (n-2)th delay for said first primary backup appliance;  
10 computer readable program code which causes said programmable computer  
11 processor to provide all or part of at least one consistent transactions set to said secondary  
12 backup appliance using said (n)th delay.

1 24. The computer program product of claim 23, further comprising:

2 computer readable program code which, if the (n-1)th delay for said first primary  
3 backup appliance is not greater than the (n-2)th delay for said first primary backup  
4 appliance, causes said programmable computer processor to establish the (n)th delay for  
5 said first primary backup appliance;

6 computer readable program code which causes said programmable computer  
7 processor to provide all or part of at least one consistent transactions set to said first  
8 secondary backup appliance using said (n)th delay for said first primary backup  
9 appliance.

1 25. The computer program product of claim 22, further comprising:

2 computer readable program code which causes said programmable computer  
3 processor to determine the (n)th mean time to complete for all (N) primary backup  
4 appliances;

5 computer readable program code which causes said programmable computer  
6 processor to determine if the (n)th time to complete for said first primary backup  
7 appliance substantially equals said (n)th mean time to complete;

8 computer readable program code which, if the (n)th time to complete for said first  
9 primary backup appliance substantially equals said (n)th mean time to complete, causes  
10 said programmable computer processor to set the (n)th delay for said first primary backup  
11 appliance equal to the (n-1)th delay for said first primary backup appliance.

1 26. The computer program product of claim 25, further comprising:

2 computer readable program code which causes said programmable computer  
3 processor to receive a standard delay adjustment;

4 computer readable program code which causes said programmable computer  
5 processor to determine if the (n)th time to complete for said first primary backup  
6 appliance is greater than said (n)th mean time to complete;  
7 computer readable program code which, if said the (n)th time to complete for said  
8 first primary backup appliance is greater than said (n)th mean time to complete, causes  
9 said programmable computer processor to set said (n)th delay for said first primary  
10 backup appliance equal to the (n-1)th delay for said first primary backup appliance minus  
11 said standard delay adjustment.

1 27. The computer program product of claim 26, further comprising computer  
2 readable program code which, if said the (n)th time to complete for said first primary  
3 backup appliance is less than said (n)th mean time to complete, causes said  
4 programmable computer processor to set said (n)th delay for said first primary backup  
5 appliance equal to the (n-1)th delay for said first primary backup appliance plus said  
6 standard delay adjustment.

1 28. The computer program product of claim 25, further comprising:  
2 computer readable program code which causes said programmable computer  
3 processor to receive a delay adjustment function;  
4 computer readable program code which causes said programmable computer  
5 processor to determine the difference between said (n)th mean time to complete and the  
6 (n)th time to complete for said first primary backup appliance;

7 computer readable program code which causes said programmable computer  
8 processor to establish the (n)th delay for said first primary backup appliance based upon  
9 said difference and said delay adjustment function.

1 29. The computer program product of claim 25, further comprising:

2 computer readable program code which causes said programmable computer  
3 processor to receive a standard delay adjustment;

4 computer readable program code which causes said programmable computer  
5 processor to predict the (n)th delay for each of said (N-1) remaining primary backup  
6 appliances using said (n)th mean time to complete, the (n)th time to complete for each of  
7 the (N-1) remaining primary backup appliances, and said standard delay adjustment;

8 computer readable program code which causes said programmable computer  
9 processor to establish the (n)th delay for the first primary backup appliances based upon  
10 the predicted delays for each of said (N-1) remaining primary backup appliances.

1 30. The computer program product of claim 22, further comprising:

2 computer readable program code which causes said programmable computer  
3 processor to receive a delay adjustment function;

4 computer readable program code which causes said programmable computer  
5 processor to predict using said delay adjustment function (N-1) delay values, wherein  
6 each of said predicted delay values is associated with a different one of the remaining (N-  
7 1) primary backup appliances;

8 computer readable program code which causes said programmable computer  
9 processor to establish the (n)th delay for the first primary backup appliances based upon  
10 said (N-1) predicted delay values.